Savannah River Site
Solid Waste Management Department
Consolidated Incinerator Facility Project
Operator Training Program

Radiological Control Topics (U)

Study Guide

ZIOITX-31

Revision 00

Training Authority / Date

Facility Authority / Date

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REVISION LOG

REV.	AFFECTED SECTION(S)	SUMMARY OF CHANGE
00	All	New Issue

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REFERENCES

1. 10 CFR 835, *Occupational Radiation Protection*

2. *Defense Nuclear Facility Safety Board Recommendation 91-6*

3. DOE Implementation Guide, G-10 CFR 835/J1-Rev. 0, *Radiological Protection Training*

4. DOE/EH-0256T, *Radiological Control Manual*, Rev. 1

5. DOE Order 5480.20, *Personnel Selection, Qualification, Training, and Staffing Requirements at DOE Reactor and Non-Reactor Nuclear Facilities*

6. 5Q Westinghouse Savannah River Company (WSRC), *Radiological Control*, March 31, 1994

7. Cohen, B.L., *Catalog of Risks Extended and Updated, Health Physics* 61, 1991

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LEARNING OBJECTIVES

TERMINAL OBJECTIVE

1.00 Given different radiological situations concerning the CIF, **DETERMINE** correct responses for each situation in accordance with the RadCon Manual (DOE and/or 5Q), approved procedures, and accepted RadCon practices, in order to maintain exposures ALARA.

ENABLING LEARNING OBJECTIVES

1.01 **DEFINE** the following terms

a. Radiation
b. Ionization
c. Radioactive Material
d. Radioactive Contamination

1.02 **DETERMINE** the differences between radiation, radioactive material, and radioactive contamination.

1.03 **DETERMINE** the relative biological risk associated with the expected sources of radiation at the CIF.

1.04 **DETERMINE** the expected sources of radiation exposure while performing operator-related activities at the CIF.

1.05 **DETERMINE** the difference between acute dose and chronic dose.

1.06 **DETERMINE** the potential for somatic effects or heritable effects to occur based on expected radiation exposures at the CIF and **DIFFERENTIATE** between the two.

1.07 **APPLY** the proper ALARA principles while working at the CIF to include:

a. Time
b. Distance
c. Shielding
d. Source Reduction
e. Exposure Limits and Control Levels

1.08 **CALCULATE** point-source dose rates at the CIF using the Inverse Square Law.

1.09 **APPLY** contamination control methods to radiological work at the CIF.

1.10 **DESCRIBE** the external and internal monitoring methods at the CIF.

1.11 **DESCRIBE** the proper use and application of the following contamination monitors at the CIF:

a. CRM

b. PCM-1B

c. PM-6A

1.12 **DETERMINE** the entry requirements for the following radiological areas at the CIF:

a. Controlled Area

b. Radioactive Material Area

c. Radiation Area

d. High Radiation Area

e. Contamination Area

f. High Contamination Area

g. Airborne Radioactivity Area

1.13 **DETERMINE** specific requirements associated with Job-specific RWPs and Standing RWPs.

RADIOLOGICAL FUNDAMENTALS

SRS Radiological Control Policy

The fundamental principle underlying the RadCon Manual is stated in "Radiation Protection Guidance to the Federal Agencies for Occupational Exposure," approved by former President Ronald Reagan on January 20, 1987:

"There should not be any ____________ ___________ of workers

to ____________ ______________ without the expectation of an

overall ___________ from the activity causing the exposure." **(Fill in the blanks.)**

The three radiological control policies that promulgate the DOE radiological control philosophy are: **(Fill in the blanks.)**

____

Personnel radiation exposure shall be maintained As-Low-As-Reasonably-Achievable.

____

Each person involved in radiological work is expected to demonstrate responsibility and accountability through an informed, disciplined, and cautious attitude toward radiation and radioactivity.

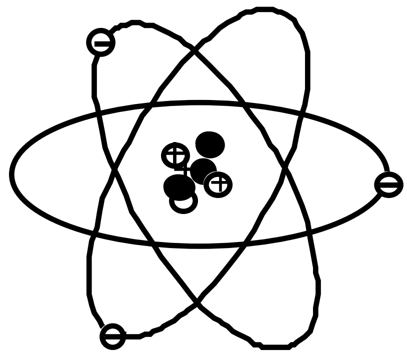
____

Excellent performance is evident when: Radiation exposures are maintained well below regulatory limits; contamination is minimal; radioactivity is well controlled; and radiological spills or uncontrolled releases are prevented.

Atoms, Ion, and Ionizing Radiation

The basic unit of matter is the atom. The three basic particles of the atom are:
(Fill in the blanks.)

- ____________________
- ____________________
- ____________________



The central portion of the atom is the nucleus, which consists of protons and neutrons. The electrons orbit the nucleus, similar to the way the planets orbit the sun.
A fundamental knowledge of atomic structure and matter is helpful in understanding radioactivity.
Most atoms are stable, but some are unstable. Unstable atoms become stable by emitting radiation.

	This event, when ionizing radiation is emitted from the nucleus of an unstable atom, is called a decay event or disintegration.
	Radioactivity can be produced, as in nuclear reactors, or it can be found occurring naturally in the earth's crust and in the surrounding universe.

1.01	**DEFINE the following terms** **a. Radiation** **b. Ionization** **c. Radioactive Material** **d. Radioactive Contamination**
1.02	**DETERMINE the differences between Radiation, Radioactive Material, and Radioactive Contamination.**

Definitions

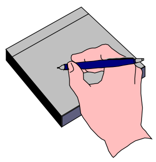
Ionization	occurs when enough energy is supplied to an atom and an electron is removed from the atom.
Resulting Charge	The resulting atom will have a positive charge.

Ionizing Radiation	is radiation that can produce charged particles (ion pairs) in any material with which it interacts, or energy in the form of particles or rays emitted from radioactive atoms that can cause ionization.
Four Basic Types	Of primary concern in the nuclear industry are alpha, beta, gamma/X-ray, and neutron radiation.

Radioactive Material	is any material containing radioactive atoms that emit radiation.

If radioactive material is properly contained, it may still emit radiation and be an external dose hazard, but it will not be a contamination hazard.

Radioactive Contamination



is ____

____.

It is important to note here that exposure to radiation does not result in a contamination of the worker. Radiation is a type of energy while contamination is a material.

Types of Ionizing Radiation

a	An alpha particle, designated by the Greek letter *a*, is a positively charged particle consisting of 2 protons and 2 neutrons. Alpha radiation is non-penetrating, but results in the most biological damage to the body.
b	A beta particle is a high-speed charged particle with moderate penetrating power. These particles, designated by the Greek letter *b*, have the characteristics of electrons and may be positively or negatively charged. Beta particles result in relatively low biological damage to the body.
g	A gamma ray, designated by the Greek letter *g*, is electromagnetic radiation emitted from the nuclei of radioactive atoms. Because gamma rays can travel through the body, they are sometimes referred to simply as "penetrating radiation." Gamma's and Beta particles cause roughly the same amount of biological damage to the body
X	X-rays are another more familiar form of ionizing electromagnetic radiation. They are like gamma rays and can penetrate human tissue. The only difference between X-rays and gamma rays is their point of origin. X-rays originate in the orbital electron shells and gamma rays originate in the nucleus of a radioactive atom. Gamma and X-rays produce the equivalent biological damage to the body.

A fourth type of ionizing radiation is ____.
Very few elements emit neutron radiation when they undergo radioactive decay. A more likely source of neutron radiation is the fission process. Neutrons, like gamma rays, are very penetrating. Neutrons cause a relatively high amount of biological damage to the body; only the Alpha particles cause more biological damage.

Alpha, beta, gamma, x-ray, and neutron radiation can all cause ionization when interacting with matter.

The three most common types of ionizing radiation we expect to encounter at CIF are:

(Fill in the blanks.)

____

____

____

Units of Measure for Radiation and Contamination

1.03	**Determine the relative biological risk associated with the expected sources of radiation at the CIF.**

Roentgen (R) - a unit of measure for gamma ray and/or x-ray exposure.

1 R = _________ mR **(Fill in the blank)**

Rad - a unit of measure for absorbed dose, or how much energy is absorbed by any material from any type of radiation.

1 rad = 1000 _________ **(Fill in the blank)**

Rem - a unit of measure for dose equivalence. It is the only unit of measure for radiation that takes into account how radiation affects the human body.

_________ = 1000 mRem **(Fill in the blank)**

Rad X Quality Factor = Rem

The units of measure for radiation are: **(Fill in the blanks.)**

____

____

____

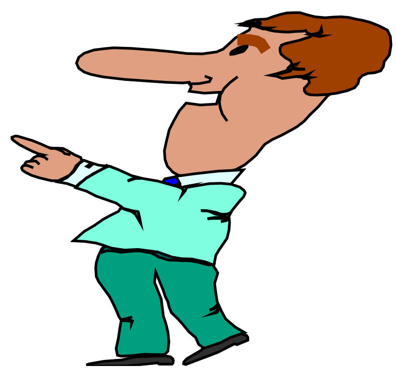
A **Quality Factor** is a means of converting a unit of absorbed dose (Rad) to equivalent biological damage (Rem). Quality Factors are based on ionizing radiations' ability to produce ionization or ion pairs. Thus, the higher the Quality Factor for a given type of radiation, the more ionization it produces in a single event.

QUALITY FACTORS
Alpha = 20
Neutron = 3-10 (depending on energy levels)
Gamma and X-rays = 1
Beta = 1

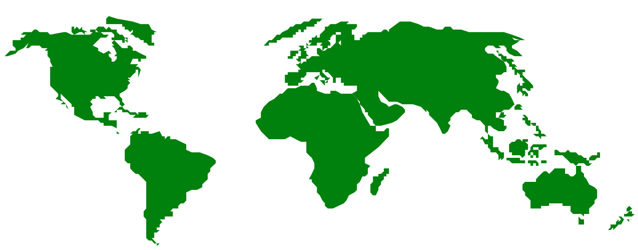
The normal unit for measuring contamination is the ____________, which stands for ___________________ _______ ________________. **(Fill in the blanks.)**

Now what exactly is a disintegration? A disintegration, or decay event, is what it's called when an unstable (radioactive) atom emits some excess energy in an effort to become stable. As discussed earlier in this lesson, another name for this excess energy is ionizing radiation.

By counting the decay events (or disintegrations) in a sample over time, the amount of activity present can be determined.



Sources of Radiation



We live in a radioactive world and always have. We have always lived in the presence of ionizing radiation from natural background sources. In fact, for the majority of us, we will be exposed to more ionizing radiation from natural background radiation than from our jobs.

1.04	**DETERMINE the expected sources of radiation exposure while performing operator-related activities at the CIF.**

The average annual radiation dose to a member of the general population from natural background and man-made sources is about __________ **millirem**. **(Fill in the blank)**

<u>Radiation Sources at the CIF</u>

The major sources of radiation exposures expected at the CIF:

Exposure from Ash Handling Tasks

Exposure from Waste Blend and Spare Tank Storage

Exposure from Offgas Support Systems

Exposure from Box Handling Tasks

Expected Dose Rates for Various Areas at the CIF

CIF Container or Tank Type	Dose Rate Distance in Feet From Exterior Surface of Container or Tank	Gamma Dose Rate Range (mR/hr)
Aqueous Waste Tank	1 to 12	0.09 to 0.01
Blend Tanks	1 to 60	78.13 to 0.59
Spare Storage Tank	1 to 210	131.11 to 0.10
OGS Recirculation Tank	1 to 15	1.46 to 0.11
OGQ Recirculation Tank	1 to 60	39.27 to 0.25
OGB Hold Tanks	1 to 60	40.2 to 0.25
Solid Waste Handling/One Box	1 to 6	0.28 to 0.02
Full Conveyors in Box Handling Area	Dose Rate Distance Taken From Assay Unit Area.	0.36 to 0.14
Full Conveyors in Box Handling Area	Dose Rate Distance Taken From X-Ray Unit Area.	1.21 to 0.33
Ash Crete Drum Area One Drum 1/3 Full of Ash	1 to 60	90.32 to 0.11
Ash Crete Drum Area One Drum Full of Ash, Cement and Water	1 to 60	59.46 to 0.06

BIOLOGICAL EFFECTS OF RADIATION

1.05	**DETERMINE the difference between acute dose and chronic dose.**

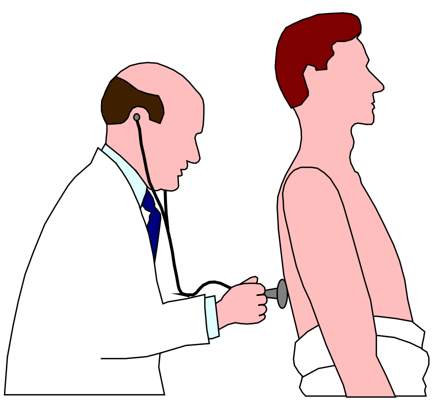
Acute Radiation Doses

Acute radiation doses are ____

____.

(Fill in the blanks.)

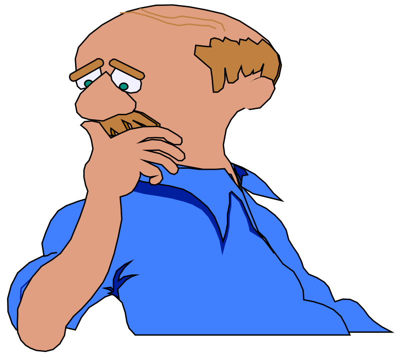
	The body can't repair or replace cells fast enough from an acute dose, and physical effects such as reduced blood count and hair loss may occur.
	Slight blood changes may be seen at acute doses of 10,000 - 25,000 mRem, but an individual would not otherwise be affected.



Radiation Sickness

At acute doses greater than 100,000 mRem, about half of the people exposed would experience nausea due to damage of the intestinal lining. Radiation therapy patients often receive whole body doses in this range and above, although doses to the region of a tumor are many times higher than this.

If the acute dose to the whole body is very large (on the order of 500,000 mRem or larger), it may cause so much damage that the body cannot recover. An example is the 30 firefighters at Chernobyl who received acute doses in excess of 800,000 mRem.



After an Acute Dose to the Whole Body

After an acute dose, damaged cells will be replaced by new cells and the body will repair itself, although this may take a number of months. Only in those extreme accidents, such as with the Chernobyl firefighters, would the dose be so high as to make recovery unlikely.

Probability of an Acute Dose

What is important to understand is that it takes a massive acute dose of radiation before any physical effect is seen. The possibility of a radiological worker receiving an acute dose of ionizing radiation on the job is extremely remote. Where there is a potential for larger exposures, many safety features are in place.

Chronic Radiation Doses

 A chronic radiation dose is typically a _________________________________

____.

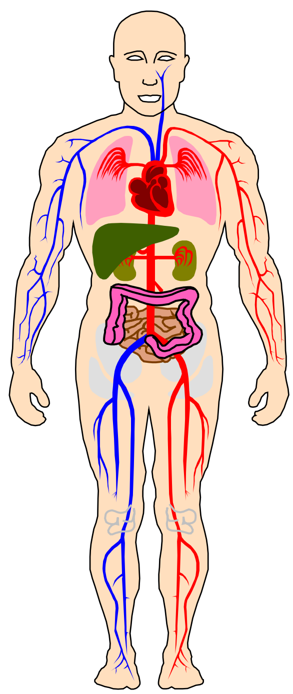
 A typical example of a chronic dose is the dose we receive from ___________

____________________ every day of our lives or the dose we receive from

_________________ _________________.

(Fill in the blanks.)

Chronic Dose Versus Acute Dose

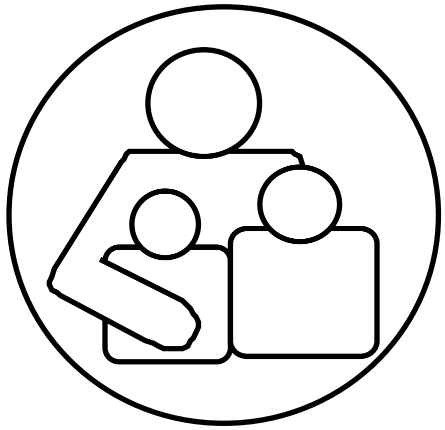


The body is better equipped to tolerate a chronic dose than an acute dose. The body has time to repair any damage because a smaller percentage of the cells need repair at any given time.

The body also has time to replace dead or non-functioning cells with new, healthy cells. It is only when the dose of radiation is so high or is received very rapidly that the cellular repair mechanisms are overwhelmed, and the cell dies before repair can occur.

A chronic dose of radiation does not result in physical changes to the body such as those seen with some acute doses.

Genetic Effects



The biological effects of concern from a chronic dose are changes in the chromosomes of a cell or direct irradiation of a fetus.

Genetic effects refer to effects to genetic material in a cell chromosome. Genetic effects can be somatic (cancer, etc.) or heritable (future generations).

1.06	**DETERMINE the potential for somatic effects or heritable effects to occur based on expected radiation exposures at the CIF and DIFFERENTIATE between the two.**

Somatic Effects

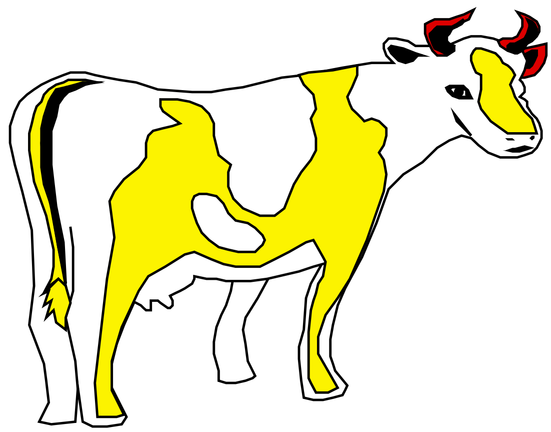
A somatic effect is one that appears in the _______________ _______________. **(Fill in the blank).**

An example of a somatic effect is cancer. The probability of this is very low at occupational doses**.**

Heritable Effects

A heritable effect is a genetic effect that is _______________ or _____________ to an _______________________. **(Fill in the blanks.)**

Heritable effects from radiation have never been observed in humans but have been observed in studies of plants and animals.



This includes the 77,000 Japanese children born to the survivors of Hiroshima and Nagasaki (these are children who were conceived <u>after</u> the atomic bombs).

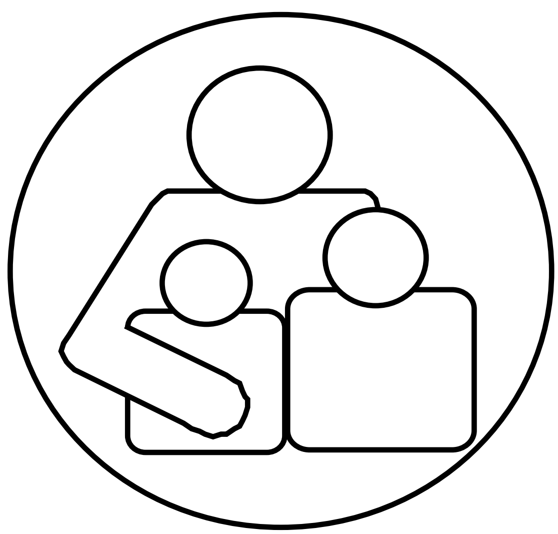
Studies have followed these children, their children, and their grandchildren.

<u>Prenatal Radiation Exposure</u>

Although no effects have been observed in Japanese children conceived after the atomic bombs, there were effects seen in some children who were exposed while in the womb to the radiation from the bombs at Hiroshima and Nagasaki.

Sensitivity of the Unborn

Embryo/fetal cells are rapidly dividing which makes them sensitive to any environmental factors such as ionizing radiation.



Potential Effects Associated with Prenatal Exposures

Exposure to certain chemical agents and/or physical conditions can potentially cause damage to an unborn child, especially early in the pregnancy.

Some children who were exposed while in the womb to the radiation from the atomic bombs were born with ____ and ______________________________________. **(Fill in the blanks.)**

It has been suggested, but not proven, that exposures to the unborn may also increase the chance of developing childhood ___________________. **(Fill in the blank)**

	Only when doses exceed 15,000 mRem is there a significant increase in risk.
	In an effort to be prudent, limits are established to protect the embryo/fetus from any potential effects which may occur from a significant amount of exposure to radiation.

ALARA

Because the risk associated with low-level exposure to ionizing radiation is not well known, the concept of ALARA has been developed.

ALARA stands for As Low As Reasonably Achievable

	Efforts should be made to reduce both internal and external exposure to ionizing radiation to levels that are As Low As Reasonably Achievable.

Basic protective measures used to reduce external exposure include consideration of four radiation protection factors that can alter radiation dose.

These four factors are: **(Fill in the blanks.)**

- ________________
- ________________
- ________________
- ________________

1.07	**APPLY the proper ALARA principles while working at the CIF to include:** **a. Time** **b. Distance** **c. Shielding** **d. Source Reduction** **e. Exposure Limits and Control Levels**

Time

Time is an important factor in radiation protection.

This principle states that the ________________ the time spent in a radiation field, the ______________ radiation will be received by the individual.**(Fill in the blanks.)**

Many radiation monitoring devices measure exposure in milliroentgens (mR) per hour. An exposure rate of 60 mR/hr means that for each minute spent in a radiation field, a person will be exposed to 1 mR (60 mR/hr divided by 60 in/hr = 1 mR/min).

Distance

1.08	**CALCULATE point-source dose rates at the CIF using the Inverse Square Law.**

The second radiation protection factor is distance.

This principle states that the ________________ a person is from a source of radiation, the _____________ the radiation dose. **(Fill in the blanks.)**

A drum of ashcrete is reading 90 mR/hr @ 1 foot. What would you expect the doserate to be at a distance of

2 feet _________

4 feet _________

8 feet _________

$D^2DR_1 = D^2DR_2$ Where:
D = Distance, DR = Dose Rate

Inverse Square Law: States that if you double the distance from the radiation source, you quarter the dose.

Shielding

The third radiation protection factor is shielding.

The principle follows that the ______________ a material, the ____________ is its ability to stop the passage of radiation. **(Fill in the blanks.)**

Shielding is not always practical during emergency field operations, and the administration of emergency care should not be delayed to seek shielding materials. Rather, the principles concerning the factors of time and distance can be used to reduce radiation exposure.

Quantity

The fourth radiation protection factor is quantity. The exposure rate from a given radioactive material is directly related to the amount or quantity of the material present.

This principle involves ________________ the quantity of _______________ _______________ in the working area to _____________ radiation exposure. **(Fill in the blanks.)**

	Any technique that reduces the amount of radiation or radioactive material in the working area is very useful.

DOE Radiation Dose Limits

The Department of Energy has established dose limits and administrative control levels in order to minimize the potential biological effects associated with exposure to ionizing radiation.

Fill in the DOE radiation dose limits for occupational workers to complete Table 1 below.

(Fill in the blanks.)

TYPE OF EXPOSURE	LIMIT
Radiological Worker: Whole Body (internal + external, DOE)	_____ rem/yr
Radiological Worker: Whole Body (SRS)	_____ rem/yr
Declared Pregnant Worker: Embryo/Fetus	____/_____
Minors and Students under age 18: Whole Body(internal + external)	_____ rem/yr
Visitors and Public: Whole Body	_____ rem/yr

Table 1 Summary of DOE and SRS Dose Limits

TABLE 1 NOTES:

1. Internal dose to the whole body shall be calculated as committed effective dose equivalent (CEDE).

   The CEDE is the resulting dose committed to the whole body from internally deposited radionuclides over a 50-year period after intake.

2. Background, therapeutic and diagnostic medical exposures shall not be included in either personnel radiation dose records or assessment of dose against the limits in this table.

3. The whole body extends from the top of the head down to just below the elbow and just below the knee.

   This is the location of most of the blood-producing and vital organs.

SRS Administrative Control Levels

- SRS Administrative Control Level: Whole Body - ________ mRem/yr.

- SRS Administrative Control Guide: Whole Body - ________ mRem/mo.

(Fill in the blanks.)

CONTAMINATION CONTROL

Comparison of Ionizing Radiation and Radioactive Contamination

Radiation is energy, while contamination is physical material.

Ionizing Radiation

Radiation that can produce charged particles (ion pairs) in any material with which it interacts, or energy in the form of particles or rays emitted from radioactive atoms that can cause ionization.

Radioactive Contamination

Recall that radioactive material is material that contains radioactive atoms.

Even when this radioactive material is properly contained, it may still emit radiation and be an external dose hazard, but it will not be a contamination hazard.

Radioactive contamination is radioactive material in an unwanted place.

1.09	**APPLY contamination control methods to radiological work at the CIF.**

Types of Contamination

Radioactive contamination can be fixed, removable/transferable, or airborne.

Fixed Contamination

Fixed contamination is ____

____.

(Fill in the blank)

Removable/Transferable Contamination

Removable/Transferable contamination is _________________________

____.

(Fill in the blank)

- Any object that makes contact with removable contamination may in turn become contaminated. This is known as cross-contamination.

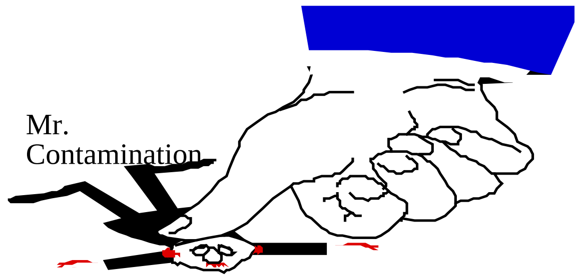
Airborne Contamination

Airborne contamination is ____

____.

(Fill in the blank)

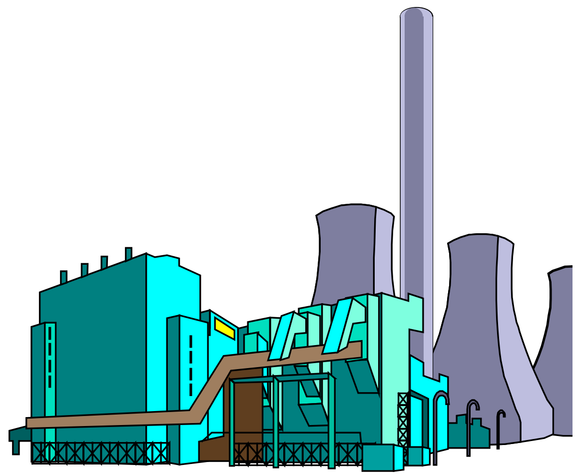
Contamination Control Methods



- Control of radioactive contamination can be achieved by proper personnel radiological practices and engineering controls.

- By controlling contamination, the potential for internal exposure and personnel contamination can be decreased.

Preventive and Engineering Control Methods



- Identify and repair leaks before they become a serious problem.
- Establish adequate work controls before starting jobs.
- While conducting pre-job briefs, discuss measures that will help reduce or prevent the spread of contamination.
- Change out gloves or protective gear as necessary to prevent cross-contamination.
- Use ventilation systems to help control airborne radioactivity levels.

Personnel Protective Measures

Protective Clothing

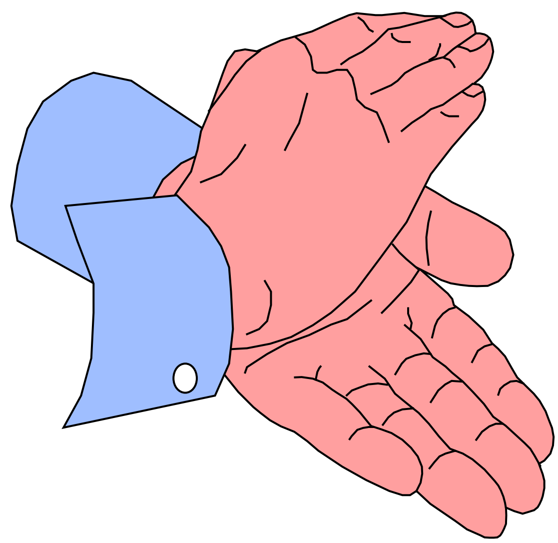
Protective clothing is not intended to stop radiation. Radiological Control personnel identify the requirements. The degree of clothing required is dependent on the work area radiological conditions and the nature of the job.

Respiratory Equipment

	Respiratory equipment is used to prevent the inhalation of radioactive materials. RCO will specify respiratory equipment requirements on the applicable RWP.

Good Work Practices

Good work practices will also help control the spread of contamination. The following are examples:



- Keep the work area neat to prevent spread of contamination.
- Comply with any procedures, work documents, or verbal instructions from Radiological Control personnel.
- Do not eat, drink, or use tobacco products in areas where radioactive material is present or while wearing protective clothing.
- Take special care when containing radioactive material in plastic bags.

The following guidelines should be used when handling contaminated materials:

Utilize protective clothing whenever possible.

Roll the sides of the bag over to protect the outside of the bag as well as the hands.

Do not force any excess air out of the bag. Forcing air out of the bag may cause radioactive materials to become airborne.

- In some cases, pointing the open portion of the bag away from the face and gently squeezing the bag to allow the air to escape may be appropriate.
- Consult Radiological Control personnel prior to utilizing this technique.

Tape the ends of any sharp items to protect the bag from being punctured.

Do not allow free-standing liquid in the bag. Instead, place an approved type of absorbent material into the bag.

Tape the ends of bag securely to prevent any leakage.

DOSIMETRY AND INSTRUMENTATION

1.10	**DESCRIBE the external and internal monitoring methods and requirements at the CIF.**

External Dosimeters

Various types of external dosimeters are used at SRS to measure

______________________ from ____________ sources of radiation.

(Fill in the blanks.)

	Radiological Control personnel will determine the type(s) of dosimetry required and when required. These requirements will be posted in RWPs and SRWPs.
	Personnel are responsible for taking proper care of their dosimetry.

Identify the purpose of each of the following dosimeters: (Fill in the blanks.)

Regular TLD measures dose from

___________,

___________, and

___________ radiation.

SRD/EPD measures dose from

___________ radiation.

Thermoluminescent Dosimeter (TLD)

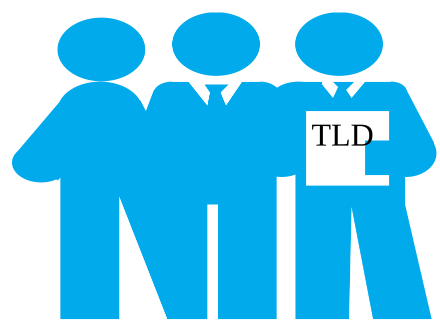
The TLD (regular or 912) is the most common type of personnel dosimeter at SRS and is used to produce an official record of dose. It is each employee's responsibility to track their exposure and return TLDs each month for processing and issuance of a new TLD for the coming month.

Theory of Operation

The TLD badge consists of a holder, filters, and thermoluminescent material. After exposure to ionizing radiation, the thermoluminescent material gives off light proportional to the amount of energy received when it is heated. The filters or windows allow RCO personnel to distinguish between beta, gamma, and x-ray radiation. Each window has a different amount of shielding to detect the various types of radiation. By comparing the exposure received by each window to one another, RCO can calculate whole body exposure from gamma and x-ray radiation, and skin dose from beta radiation.

Correct Use of TLDs

- ✓ Wear TLD when required. We will discuss these requirements later.
- ✓ The TLD (regular or special) must be worn on the chest area between the waist and the neck. The beta window is placed facing away from the body.



Actions for Lost, Damaged, or Contaminated Dosimeter

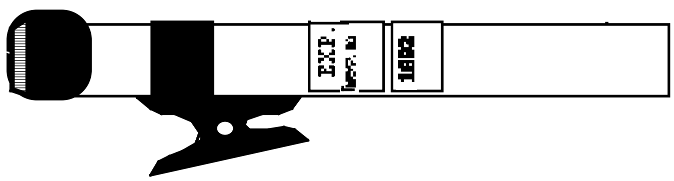
While in an area controlled for radiological purposes, take the appropriate actions if <u>any</u> dosimeter is lost, damaged, or contaminated.

These actions include:

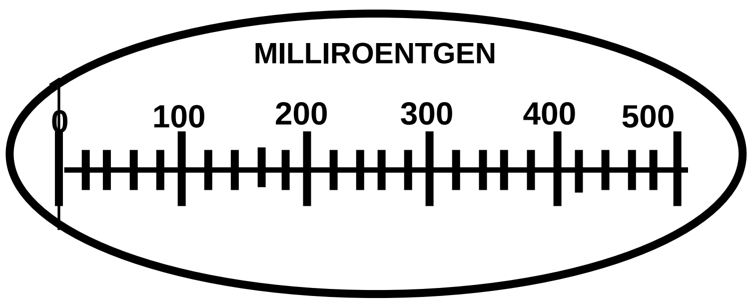
- ✓ Place work activities in a safe condition.
- ✓ Alert others.
- ✓ Immediately exit the area.
- ✓ Notify Radiological Control personnel.

Self-Reading Dosimeters (SRDs)

SRDs are used in addition to the TLD to allow individuals to determine, at a glance, their estimated amount of gamma or x-ray exposure.



0-500 mR Range

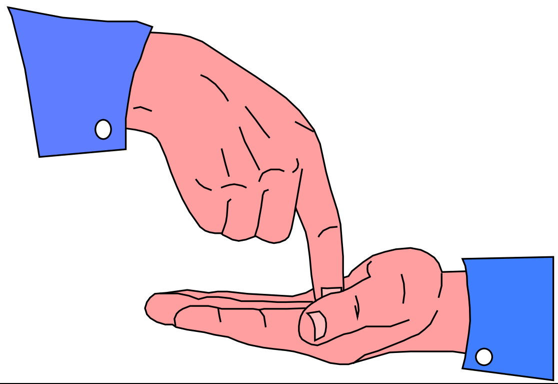


Correct Use of an SRD

- Wear SRDs properly and when required. When SRDs are required, they shall be worn within close proximity to the primary dosimeter.
- Check for a valid calibration sticker on the SRD. SRD calibrations are good for 6 months.
- Read the SRD properly. Point the end toward a light source and look into the lens. The dosimeter scale should be in a horizontal position with the zero to the left and the highest number to the right. Determine your exposure by subtracting the initial SRD reading from the final reading.
- Read the SRD frequently. Contact Radiological Control personnel to find out how often the SRD should be read and the technique to use when reading it.
- While working, don't allow your SRD to go past 3/4 scale (375 on a 0 - 500 mR SRD).
- Upon exiting the area, fill out your employee dose record card.

If your SRD approaches or reaches 3/4 scale, you must take the following actions:

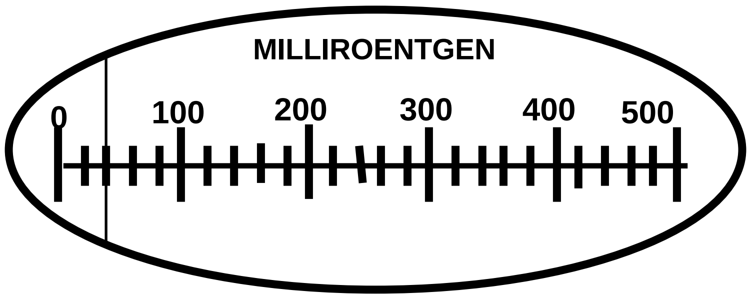
- Leave the area immediately.
- Place work in a safe condition and inform others why you are leaving.
- Have Radiological Control personnel re-zero the SRD and record your exposure.



Correct Use of an SRD (Continued)

- Identify an "irregular" or "off-scale" reading.
  - When the SRD reading is more than originally estimated for the amount of time in the area, the reading is considered "irregular."
  - If the hairline is below the zero reading, above the highest reading, or missing, the reading is considered "off-scale."
- Contact Radiological Control personnel immediately if the SRD is dropped. If the SRD is dropped in liquid or an unsafe location, do not retrieve it.

Initial Reading

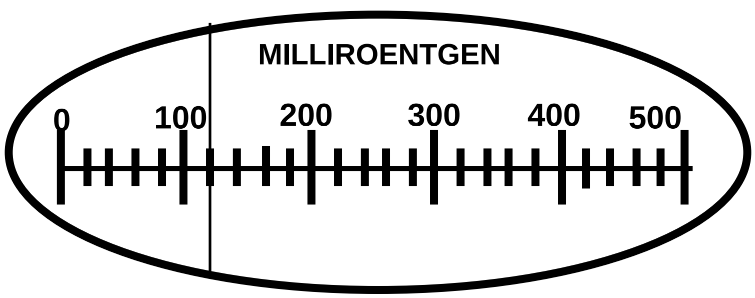


Final Reading ______

- Initial Reading ______

Total ______

Final Reading



Electronic Personnel Dosimeters (EPDs)

Electronic Personnel Dosimeters (EPDs) are battery-operated gamma radiation detectors. EPDs offer many conveniences for monitoring radiation exposure on the job. These small electronic devices, not much larger than a pager, can be set to alarm at a specific accumulated dose and/or dose rate. The output display is easier to read than an SRD and there is no guesswork involved as to when you should exit your work area. The EPD will alarm at the designated setpoint to alert you to exit the area.

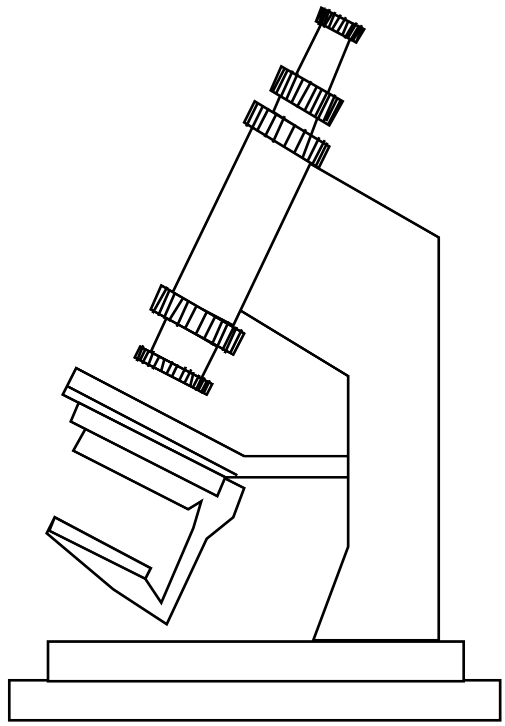
1.10 DESCRIBE the external and internal monitoring methods at the CIF.

Internal Monitoring

If radioactive material enters the body, the material is an internal source of exposure until it is eliminated from the body.

The radiation dose limits for the whole body are based on the sum of internal and external radiation sources.

- Natural radioactivity in the food we eat and the water we drink, the air that we breathe, medical procedures that use radioactive materials, and radioactive contamination are potential sources of internal exposures.
- Accidental or inadvertent internal uptake of radioactive material (internal contamination) can cause additional dose to the whole body or individual organ(s).



Internal Monitoring Methods

To indirectly measure the amount of radioactive material present inside the body, whether from naturally occurring or inadvertent uptakes, ___________ __________ counters, ____________ counters, and/or ______________ samples may be used. From this measurement, an internal dose may be calculated. **(Fill in the blanks)**

Whole Body Counter (WBC)

Whole body counters detect gamma radiation emitted from radioactive materials in the body. A yearly WBC is required at a minimum. Baseline WBC's required prior to entry into RCA.

Chest Counter

The chest counter will detect low energy X-rays and gamma rays emitted from material in the body.

Bioassay Samples

Bioassay samples (urine or fecal samples) are used to find out if alpha- or beta-emitting material has entered the body. Sample may be required based on your facility assignment.

A baseline bioassay sample may be required prior to entry into an RCA. Contact RCO personnel in your area to determine the specific requirements for that area. The frequency in which samples are submitted depends on your work assignment and may be found on your Radiological Qualification Badge.

Personnel Responsibilities Concerning SRS Internal Monitoring Program
(Fill in the blanks.)

Unless an individual is on a routine bioassay program at SRS, he/she should

receive a __________ ________ count and/or a ___________ count, and leave

_____________ samples at the direction of Radiological Control personnel.

Also, ___________ __________ __________ (RCO) personnel can be consulted

if any questions arise concerning the internal monitoring program at SRS.

Potential Sources of Internal Exposures at the CIF

- Exposure to the spilled contents of a box of waste during Box Handling operations
- Exposure to contamination from Ash Handling operations
- Exposure to radioactive material from process system leaks or ruptures
- Exposure to radioactive material from Off Gas System HEPA filter failure

Instrumentation

Portable Survey Instrument Pre-Operational Checks

Instrument design, use, selection, and response characteristics are all invalid if the instrument used is not properly calibrated, battery checked, source checked, and damage free.

Calibration Check

The calibration check is performed by verifying the correct information on the calibration sticker.

Damage Check

A damage check is also performed to ensure that the instrument is in proper working condition.

It consists of checking:

- Instrument's probe and cords for physical damage
- Meter face for cracks
- Cord for loose connections
- Detector window is not torn or punctured

Battery Check

A battery check is performed by moving the range selector switch to the "batt check" position.

The needle of the instrument will move to the "battery OK" range of the meter scale if the batteries are good.

1.11	**DESCRIBE the proper use and application of the following contamination monitors at the CIF:** **a. CRM** **b. PCM-1B** **c. PM-6A**

Types of Contamination Monitors

There are several types of contamination monitors at SRS used primarily to check for external beta/gamma contamination. These include the:

- __________ _________ ___________ (CRM),
- _____________ ______________ ___________ (PCM-1B), and
- ____________ ____________ (PM-6A). **(Fill in the blanks.)**

	We will discuss only the CRM in detail.
	Procedures for using a PCM-1B and PM-6A are posted at each monitor, and personnel are available for assistance in using them if needed.

Count Rate Meter (CRM)

CRMs are used:

- to manually check for external contamination on personnel, surface areas, tools, etc. This is referred to as "frisking."
- to detect radioactive material (contamination) that emits alpha, beta, and/or gamma radiation.
- at exits from contamination areas and as a backup to other personnel monitors.

CRM's provide an indication of ______________________ levels through the use of a metered scale and audible signals (the metered scale is divided from 0 to 500 cpm). **(Fill in the blank)**

Proper Use of the CRM

- Read and follow posted instructions.
- Verify the instrument is in working order before touching the meter or probe:

CRM Guidelines

- Check the on/off switch.
- Set the instrument to the proper scale (normally this is x1).
- Notice needle movement.
- Ensure audio can be heard (clicking noise).
- Survey/frisk hands before picking up the probe.
- Perform instrument response check (as applicable).

- Note background radiation level. Background radiation is the radiation that is present in the area where the count rate meter is used.

- Hold the probe approximately 1/4" from the surface being surveyed for beta/gamma and alpha contamination.

- Move the probe slowly over the surface, approximately 2" per second.

Perform a whole body survey in the following order:

- Head (pause at mouth and nose for approximately 5 seconds)
- Neck and shoulders
- Arms (pause at each elbow)
- Chest and abdomen
- Back, hips, and seat of pants
- Legs (pause at each knee)
- Shoe tops
- Shoe bottoms (pause at sole and heel)
- Personnel and supplemental dosimeters

Note: The whole body survey should take 2 - 3 minutes.

- If the count rate increases during frisking, pause for 5 - 10 seconds over the area to provide adequate time for instrument response.

- If any personnel items are taken into an RBA, they must be surveyed upon exit (e.g., pens, glasses, notebooks, etc.). Have these items available for survey and not tucked away in pockets.

- Carefully return the probe to its holder.

CRM Alarm Condition

A red light illuminates and a loud high-pitched sound is heard.

Appropriate Response if Contamination is indicated (If the CRM alarm sounds)

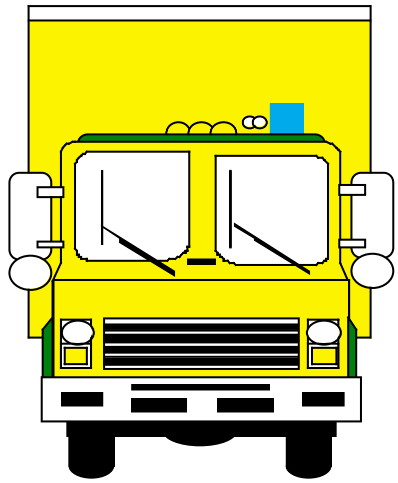
✓ Remain in the immediate area.
✓ Notify Radiological Control personnel:
    ✓ Yell for help or send someone to phone for help.
    ✓ As a last resort, take the most direct route to the nearest phone or person.
    ✓ Remember the path taken and, if possible, identify the area to prevent others from crossing your path.

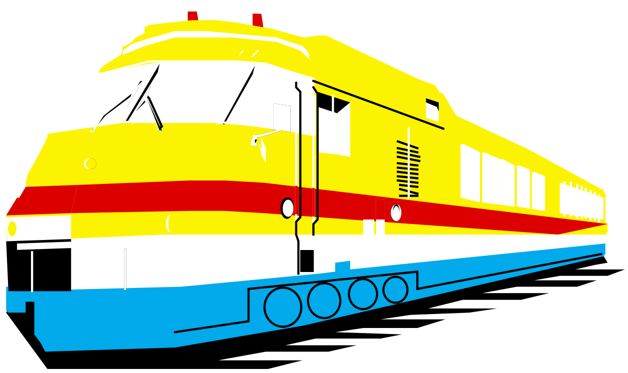
RADIOLOGICAL POSTINGS AND REQUIREMENTS

Transportation Placards and Labels

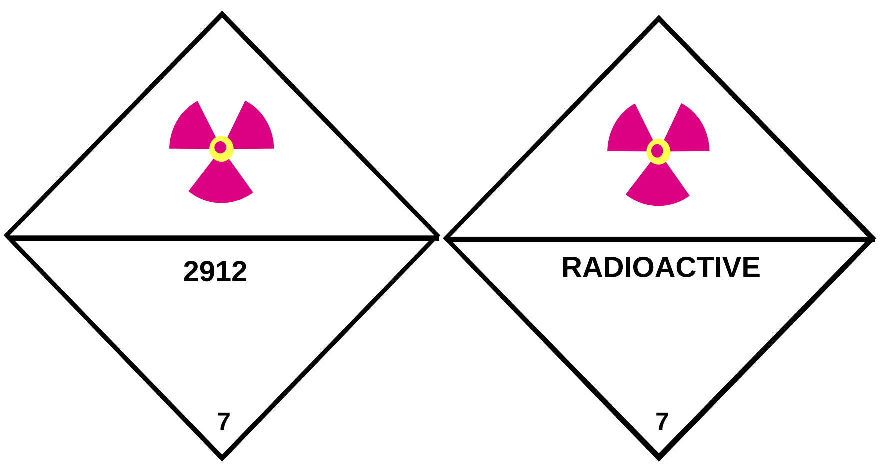
Motor vehicles, rail cars, and freight containers often display radioactive warning placards when transporting certain types and quantities of radioactive materials (see Figure 1, *Typical Radioactive Warning Placards*).

As a guideline, the presence of such placards indicates that radiological safety controls might be necessary during emergency response activities.





Every shipment of radioactive material should be accompanied by documents, such as shipping papers or bills of lading, which are of great value in assessing exposure potential in transportation accidents.



Standard size is approximately 10 x 10 inches

Figure 1, Typical Radioactive Warning Placards

- Three different labels, white-I, yellow-II, or yellow-III are used on the external surface of packages containing radioactive material, as illustrated in Figure 2, *Labels Required On Package Exterior.*

- The shipper chooses and applies the label based upon Department of Transportation (DOT) regulations governing the external radiation level, or in some cases, the type and quantity of radioactive material within the package.

- Package labels specify the contents and the activity in curies.

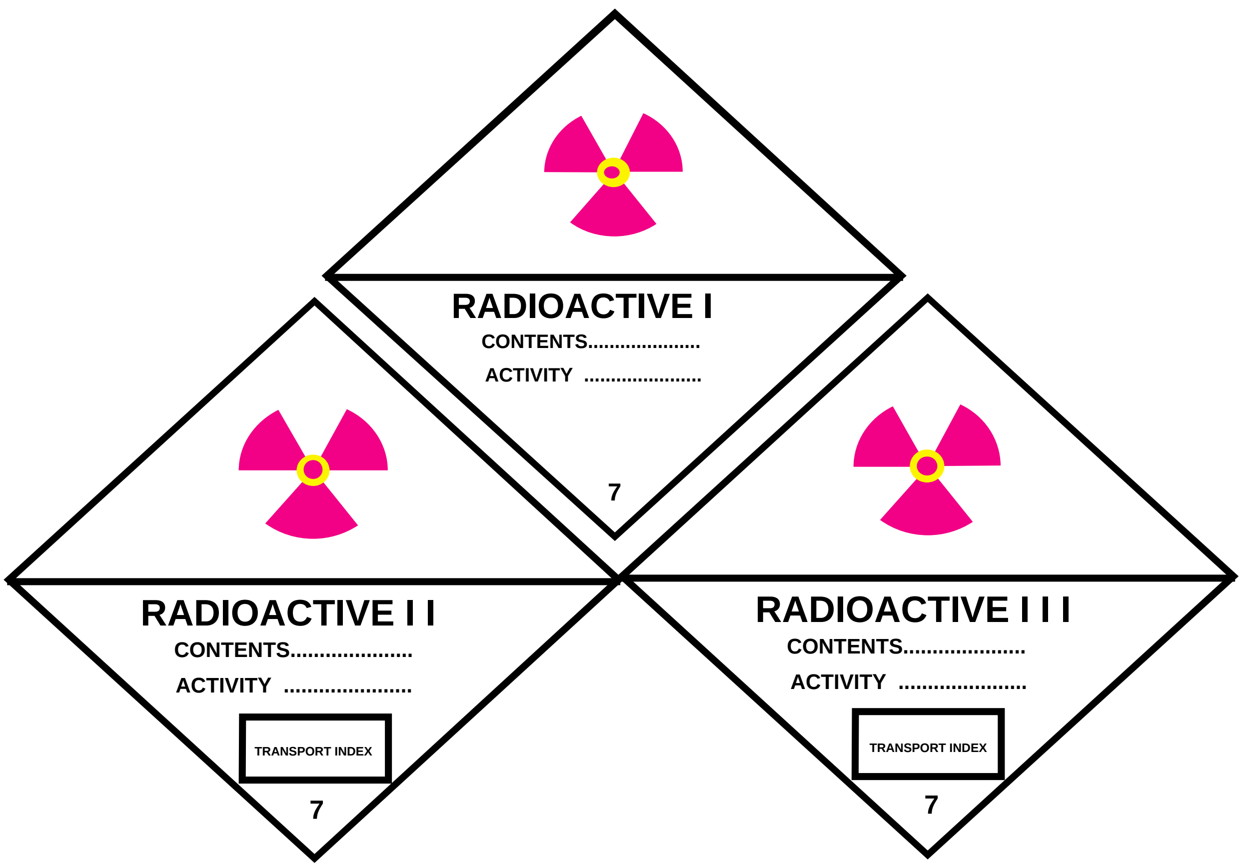
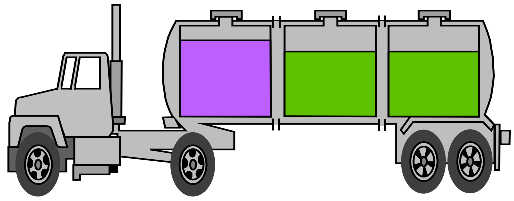


Figure 2, Labels Required On Package Exterior

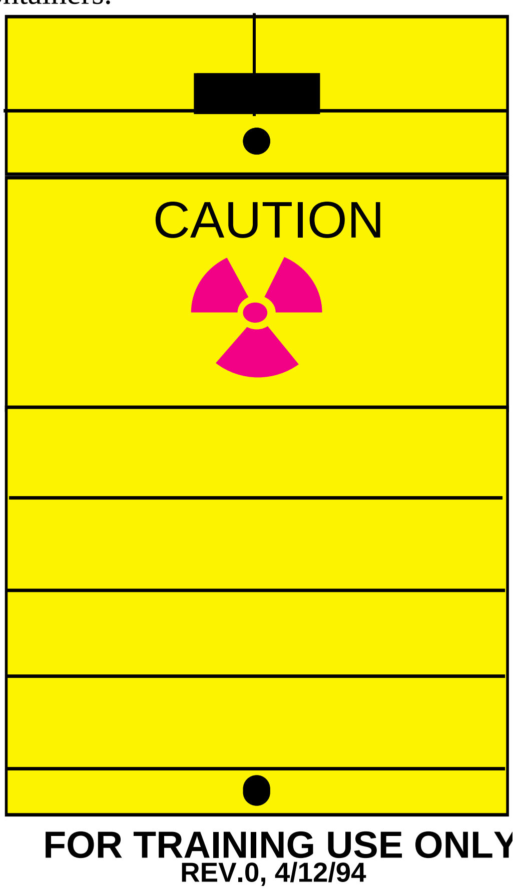
Yellow-II and yellow-III levels also specify the transport index (TI), which is equal to the maximum radiation level (measured in mRem/hr) at 3 feet from the undamaged package.



Radiological Postings and Controls

Figure 3 below, illustrates signs or labels indicating the presence of radiation or radioactive materials.

Remember, whenever radioactive materials or radiation generating devices such as an x-ray machine or accelerators are used, their presence will usually be indicated by posted signs on entry doors, storage vaults, cabinets, or containers.



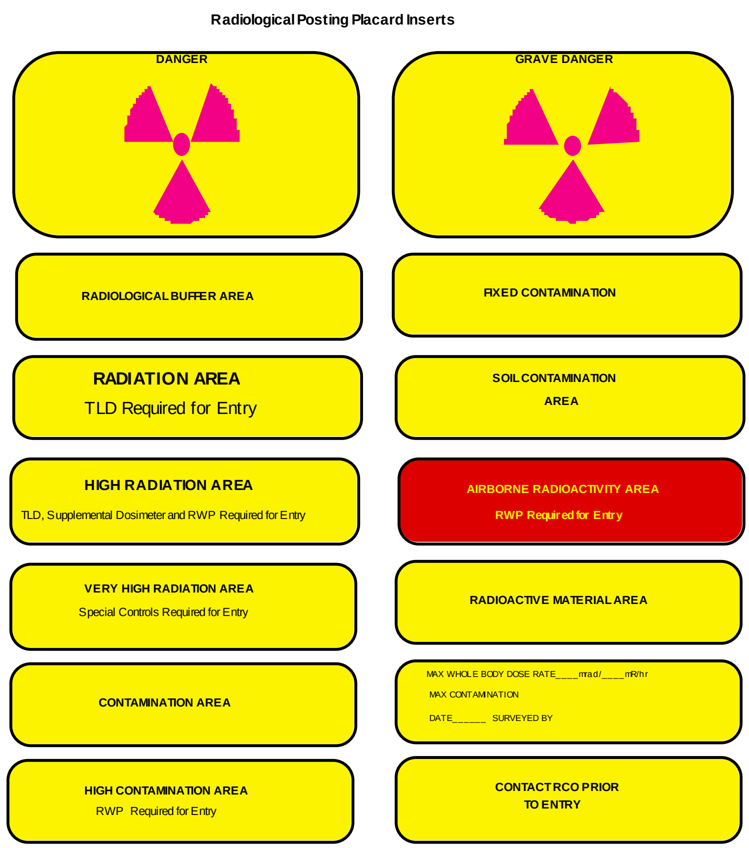


Figure 3, Typical Radiological Posting Signs

1.12	**DETERMINE the entry, exit, and posting requirements for the following radiological areas at the CIF:**
a.	**Controlled Area**
b.	**Radiological Buffer Area**
c.	**Radiation Area**
d.	**High Radiation Area**
e.	**Contamination Area**
f.	**High Contamination Area**
g.	**Airborne Radioactivity Area**
h.	**Radioactive Material Area**

Controlled Area

Each access point to a Controlled Area shall be posted, identifying it as a Controlled Area. Areas within the site boundary should be clearly posted to alert personnel to the presence of radiation and radioactive materials above natural background levels.

Radiological Buffer Area (RBA)

Radiological Buffer Areas shall be established within the Controlled Area to provide secondary boundaries to minimize the spread of contamination and to limit doses to general employees who have not been trained as radiological workers. It is not expected that Radiological Buffer Areas will be established around inactive or secured Contamination Areas.

The Radiological Buffer Area is intended for use where ongoing work activities may create airborne radioactivity or the spread of contamination. The size of the Radiological Buffer Area should be commensurate with the potential for the spread of contamination outside Contamination, High Contamination and Airborne Radioactivity Areas. At a minimum, the Radiological Buffer Area should include the area adjacent to any exit from and entrance to Contamination, High Contamination and Airborne Radioactivity Areas.

Entry Requirements

- RWT I or II Training
- Minimum dosimetry is a TLD
- Whole Body Count as appropriate
- Radiological Qualification Badge in possession
- Signed in on applicable RWP
- Submittal of appropriate bioassay samples

Exit Requirements (RBA)

- Workers must monitor for contamination per instructions posted at the RBA exit before exiting.
- Personal items must also be monitored (papers, notebooks, flashlights, etc.).
- Workers must record time and exposure on the RWP, when applicable.

Radiation Area

Areas shall be posted to alert personnel to the presence of external radiation at levels >5 mR/hr to $\leq$ 100 mR/hr at 30 cm. The requirement for personnel dosimetry should be included on the sign. The requirement for an RWP should be included either on or in conjunction with the posting.

Entry Requirements

- At a minimum, all requirements for the RBA must be met.
- TLD and SRD as appropriate
- RWT I or II Training

Exit Requirements

- Workers must record time and exposure on the RWP, when applicable.

High Radiation Area and Very High Radiation Area

High Radiation Areas shall be posted to alert personnel to the presence of external radiation at levels >100 mR/hr at 30 cm to $\leq$ 500 Rad/hr at 100 cm.

Very High Radiation Areas shall be posted to alert personnel to the presence of external radiation at levels >500 Rad/hr at 100 cm.

Entry Requirements

- At a minimum, all requirements for the RBA must be met.
- RWT II Training
- TLD and SRD
- Worker must sign in on a job-specific RWP.
- Survey meter or dose rate indicating device must be available at the work area.
- Access points will be secured by control devices, locks, guards, etc.
- Additional requirements are necessary where dose rates exceed 1 rem/hour.

Exit Requirements (Radiation Areas)

- Workers must record time and exposure on the RWP, when applicable.

Contamination Area, High Contamination Area, Airborne Radioactivity Area

Areas shall be posted to alert personnel to contamination if specific limits are exceeded.

Contamination Area Limits		High Contamination Area Limits
• Alpha	>20 ≤2000	• >2000
• Beta/Gamma	>1000 ≤100,000	• >100,000
• Tritium	>10,000 ≤1,000,000	• >1,000,000

Note: Expressed in units of dpm/100 cm^2.

Table 2, Contamination Limits

Airborne Radioactivity Areas will be posted if airborne levels exceed 10% of any DAC value listed in 10CFR 835.

DAC stands for derived air concentration. If you breathed air at a concentration of 1 DAC forty hours a week for fifty weeks a year, your internal whole body exposure would be 5 rem. Since areas are posted at 10% of 1 DAC value, you are assured of not exceeding any limits.

Entry Requirements for all Contamination Area, High Contamination Area, Airborne Radioactivity Area

- At a minimum, all requirements for the RBA must be met.
- RWT II Training
- Personnel dosimeters, as appropriate
- Worker must sign in on a job-specific RWP.
- Protective clothing/equipment must be worn as required by the RWP.
- A pre-job briefing must be given for High Contamination and Airborne Radioactivity Areas.
- Respiratory protection worn as specified by the RWP.

Exit Requirements

- Exit only at the step-off pad.
- Remove protective clothing in accordance with posted instructions.
- Perform a whole body contamination survey.

Radioactive Material Area

- Areas where radioactive materials are used, handled or stored should be posted "CAUTION, RADIOACTIVE MATERIAL."
- Radioactive Material Areas should be located within Controlled Areas.
- Radioactive Material Areas are not required when the radioactive material in any one location is inside a Contamination, High Contamination, or Airborne Radioactivity Area.

Entry Requirements

- At a minimum, all requirements for the RBA must be met.
- If dose rates exceed 5 mrem/hour in the area, then entry requirements will be the same as those of a radiation area.

CIF Radiological Area Posting Plan

The CIF will initially be posted based upon expected radiation and contamination levels at the time of facility startup. CIF Building 261_H and Tank Farm 262-H will be posted as one large contiguous Controlled Area (refer to shading on the diagram). The CIF RCO office will also be posted as a Controlled Area. All buildings with the exception of the HEPA Area, Control Room, Electrical Rooms, Ashout Area, and Airlock will be posted as a Radioactive Material Area (refer to shading on the diagram). The Ashout Area will be posted as a Contamination Area and the airlock will be posted as a Radiological Buffer Area. A count rate meter (CRM) will be installed at the airlock exit to monitor personnel leaving the Contamination/ Radiological Buffer Area for contamination

To ensure adequate personnel monitoring, all personnel exiting the facility should monitor for contamination at the facility gate. The facility will be requested to install several PM-6 personnel contamination monitors at the perimeter fence main exit point. See *Figure 4, Facility Radiological Posting*

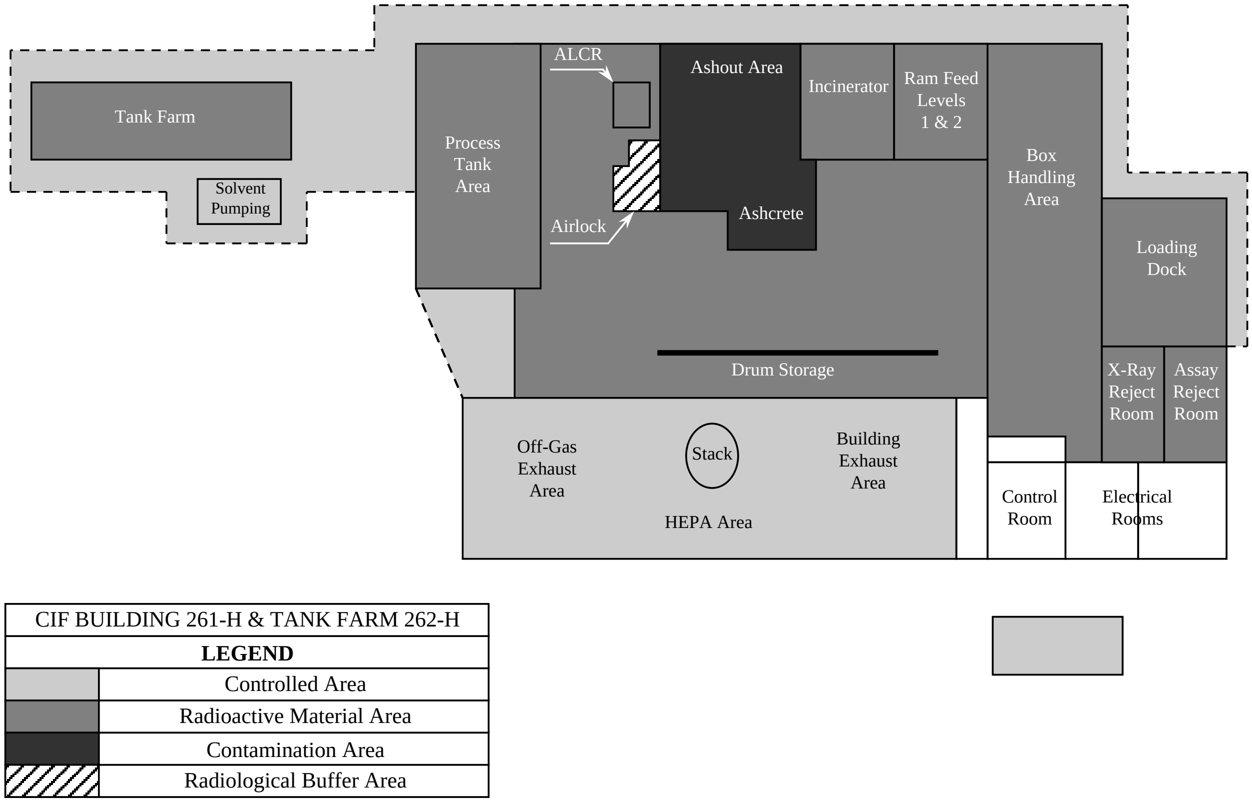


Figure 4, Facility Radiological Posting

RADIOLOGICAL WORK PERMITS

1.13	**DETERMINE specific requirements associated with Job-specific RWPs and Standing RWPs.**

RWPs and SRWPs

The Radiological Work Permit (RWP) is an administrative mechanism used to establish radiological controls for intended work activities. The RWP informs workers of area radiological conditions and entry requirements and provides a mechanism to relate worker exposure to specific work activities. The RWP should include the following information:

1. Description of work
2. Work area radiological conditions
3. Dosimetry requirements
4. Pre-job briefing requirements, as applicable
5. Training requirements for entry
6. Protective clothing and respiratory protection requirements
7. Radiological Control coverage requirements and stay time controls, as applicable
8. Limiting radiological conditions that may void the RWP
9. Special dose or contamination reduction considerations
10. Special personnel frisking considerations
11. Technical work document number, as applicable
12. Unique identifying number
13. Date of issue and expiration
14. Authorizing signatures.

Job-Specific RWPs

These shall be used to control nonroutine operations or work in areas with changing radiological conditions. The job-specific RWP shall remain in effect only for the duration of the job.

General RWPs

These may be used to control routine or repetitive activities, such as tours and inspections or minor work activities, in areas with well-characterized and stable radiological conditions. General RWPs should not be approved for periods longer than 1 year.

- Radiological surveys shall be routinely reviewed to evaluate adequacy of RWP requirements. RWPs shall be updated if radiological conditions change to the extent that protective requirements need modification.
- RWPs should be posted at the access point to the applicable radiological work area.
- Workers shall acknowledge by signature or through electronic means where automated access systems are in place that they have read, understand and will comply with the RWP prior to initial entry to the area and after any revisions to the RWP.

Radiological Fundamentals

SRS Radiological Control Policy (Page 9)
"There should not be any ***occupational exposure*** of workers to ***ionizing radiation*** without the expectation of an overall ***benefit*** from the activity causing the exposure."

SRS Radiological Control Policy (Page 9)
1) ***ALARA***
2) ***Ownership***
3) ***Excellence***

Atoms, Ion, and Ionizing Radiation (Page 10)
- ***Protons***
- ***Neutrons***
- ***Electrons***

Definitions (Page12)
radioactive material in an unwanted place.

Types of Ionizing Radiation (Page 13)
- ***alpha particles***
- ***beta particles***
- ***gamma rays***

Types of Ionizing Radiation (Page 13)
neutron radiation.

Units of Measure for Radiation and Contamination (Page 14)
- ***Roentgen (R)***
- ***Rad***
- ***Rem***

Units of Measure for Radiation and Contamination (Page 14)
dpm, which stands ***for disintegrations per minute.***

Units of Measure for Radiation and Contamination (Page 13)
1 R = ***1000*** mR
1 rad = 1000 ***mrad***
1 rem = 1000 mRem

Sources of Radiation (Page 15)
360 millirem.

Biological Effects

Acute Radiation Doses (Page 17)
large doses of radiation received in a short period of time

Chronic Radiation Doses (Page 19)
small amount of radiation received over a long period of time.
natural background, occupational exposure

Genetic Effects (Page 20)
Somatic effect is one that appears in the ***exposed individual***.
A heritable effect is a genetic effect that is ***inherited*** or ***passed on*** to an ***offspring.*** (Page 16)

Potential Effects Associated with Prenatal Exposures (Page 22)
low birth weights and ***mental retardation***
cancer

Basic Radiation Protection Principles

The ALARA Program (Page 23)
These factors are ***time, distance, shielding***, and ***quantity.***

Time (Page 24)
shorter, less

Distance (Page 24)
farther, lower

Shielding (Page 25)
denser, greater

Quantity (Page 25)
limiting, radioactive material, decrease

Table 1. Summary of DOE Dose Limits (Page 26)
LIMIT - ***5.0 rem/yr, 2.0 rem/yr, 15.0 rem/yr, 50.0 rem/yr, 50.0 rem/yr,***
0.5 rem/9 mos., 0.1 rem/yr, 0.1 rem/yr

SRS Administrative Control Levels (Page 27)
700 mRem/yr, 100 mRem/mo.

Fixed Contamination (Page 29)
contamination that cannot be readily removed from surfaces.

Removable/Transferable Contamination (Page 29)

***contamination that can be readily removed from surfaces*.**

Airborne Contamination (Page 29)
***contamination (radioactive material) suspended in air*.**

Dosimetry and Instrumentation

External Dosimeters (Page 33)
personnel dose from ***external*** sources of radiation.

- Regular TLD measures: ***dose from beta, gamma, and x-ray radiation***. (Page 33)
- SRD/EPD measures: ***dose from gamma and x-ray radiation***. Page 33)

- ***120 mR - 40 mR = 80 mR*** (Page 37)

Internal Monitoring Methods
whole body counters, ***chest*** counters, and/or ***bioassay*** samples may be used. (Page 38)

Personnel Responsibilities Concerning SRS Internal Monitoring Program
whole body, chest, bioassay (Page 39)
Radiological Control Operations

Types of Contamination Monitors (Page 41)

- ***Count rate meter*** (CRM),
- ***Personnel contamination monitor*** (PCM-1B), and
- ***Portal monitor*** (PM-6A).

Count Rate Meter (CRM) (Page 42)
contamination